THE EFFECT OF ISOKINETIC EXERCISE FOR PREHABILITATION: ACL
RECONSTRUCTION

A Thesis
Submitted to the Faculty of Graduate Studies and Research
In partial Fulfillment of the Requirements
For the Degree of

Master of Science
in
Kinesiology and Health Studies
University of Regina

by
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Regina, Saskatchewan
March 2019

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Erin Edith Ann Tyson, candidate for the degree of Master of Science in Kinesiology & Health Studies, has presented a thesis titled, *The Effect of Isokinetic Exercise for Prehabilitation: ACL Reconstruction*, in an oral examination held on October 2, 2018. The following committee members have found the thesis acceptable in form and content, and that the candidate demonstrated satisfactory knowledge of the subject material.

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*via Zoom Conferencing*
Abstract

Preparing for the stress of Anterior Cruciate Ligament Reconstruction (ACLR) surgery through prehabilitation may improve strength and function before surgery, and if effective, has the potential to contribute to postoperative recovery. The purpose of this experimental study was to investigate the effectiveness of using isokinetic exercise for prehabilitation of patients with complete ACL tears, awaiting ACLR surgery. Patients with complete ACL tears, and scheduled for ACLR were randomized into the isokinetic exercise training group or the control group.

The isokinetic exercise training group completed an isokinetic strengthening program that included isokinetic concentric exercise for the injured knee, 20 times over 8 weeks before their ACLR. The control group did not receive the treatment. Both groups were encouraged to continue any exercise or activities they were currently participating in.

Leg strength (isokinetic peak torque for knee extension and flexion) was assessed before randomization at baseline (T1), again 8-weeks (T2) preoperative, and 24-weeks (T3) postoperative. In addition, at 24-weeks (T3) postoperative, the single leg hop test for distance was added as a functional measure.

Following the 8-week exercise intervention, quadriceps peak torque improved ($p<0.05$) from baseline in the exercise group compared to the control group at all three isokinetic speeds: 60°/sec, 120°/sec and 180°/sec. At 24-weeks post-surgery, quadriceps peak torque was still higher compared to the control group at two isokinetic speeds: 60°/sec, 120°/sec ($p<0.05$), and approached significance at 180°/sec ($p=.059$). At 24-weeks post-surgery, quadriceps peak torque at 60°/sec in the exercise group had
improved from baseline measures ($p<0.05$) and approached statistical significance at 120°/sec ($p=.053$), compared to the control group. At 24-weeks post-surgery, the exercise group performed better on the single leg hop test, than the control group ($p<0.05$).

Participants in the isokinetic exercise group had higher quadriceps peak torque both pre- and postoperatively compared to the control group ($p<0.05$). This increased peak torque lead to improved function, as reflected in the single leg hop tests scores ($p<0.05$). These results reflect that improving quadriceps strength preoperatively contributes to stronger quadriceps postoperatively. Improved quadriceps strength postoperatively would assist patient adaptation to the rehabilitative process, as well as increase quality of life and slow the progression of osteoarthritis. The rehabilitative process may be accelerated, allowing the patient to return to sport and activity sooner, and potentially prevent re-injury. This study supports prehabilitation for patients awaiting ACLR, however further studies need to be done to develop guidelines and protocols. Longitudinal research should examine the effects of prehabilitation programs for years after ACLR and include analysis of return to sport outcomes.

Keywords: ACL, prehabilitation, ACL Reconstruction, Isokinetic, Exercise Training, Preoperative Exercise, ACL Deficient
Acknowledgments

I began this journey in 2012, when I was researching protocols for isokinetic prehabilitation for a client who was waiting for a knee replacement. Working as a clinician, we often had success in our clinic using isokinetics for prehabilitation and rehabilitation. I had learned so much from physiotherapists I’d worked with over the years and from the insight and experiences of my clients. The concept of prehabilitation wasn’t new. The theory of strengthening before surgery to build and maintain strength after surgery seemed logical. So, you can imagine my surprise to dive into the research, and find so little on prehabilitation in orthopaedics, and nearly nothing on isokinetic protocols for this purpose. Therefore, in the end, I started this journey to validate what I had observed in my practice as an exercise therapist, and to, in some small way, help all those people who are undergoing knee replacements and ACL reconstructions.

Thank you to my husband, Brett Tyson, for being my rock in the tough times - without your support and love I would not have made it to this point. To Drs. Reed and Dash, and Louise Ashcroft; thank you for your contributions to this study, as well as your advice and support - it would not have been possible without you. Thank you to Leanne Deiter, and Danielle Houle - this project would not have been possible without your support and assistance. Finally, to Drs. Patrick Neary, Paul Bruno, Darren Candow, John Barden, Harold Reimer, Don Sharpe and Kim Dorsch - thank you for the guidance in my pursuit of knowledge, and to Dr. Stuart-Hill for serving as my external examiner. I truly appreciate everyone’s efforts on my behalf.

I can’t thank you all enough!
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List of Abbreviations, Symbols and Nomenclature

ACL- Anterior Cruciate Ligament
ACL R – Anterior Cruciate ligament Reconstruction
BMI – Body Mass Index
BP – Blood Pressure
BPTB – Bone Patella Tendon Bone
BTB – Bone Tendon Bone
%BW – Percentage of body weight
CSEP – Canadian Society for Exercise Physiology
CKC – Closed Kinetic Chain
ft-lbs – Foot Pounds
HQ – Hamstring to quadriceps ratio
HR – Heart Rate
IKDC – International Knee Documentation Committee
KOOS – Knee Injury and Osteoarthritis Outcome Score
LSI – Limb Symmetry Index
MAX GET – Maximum Gravitational Effect
NAR - Norwegian Research Centre for Active Rehabilitation
OA - Osteoarthritis
OKC – Open Kinetic Chain
ROM- Range of Motion
STG – Semitendinosus and gracilis
TKA - Total Knee Arthroplasty
The Effect of Isokinetic Exercise for Prehabilitation: ACL Reconstruction

1.0 Introduction

The American Orthopaedic Society for Sports Medicine reported in 2008 that approximately 150,000 anterior cruciate ligament (ACL) injuries occur in the United States each year. Health care costs for ACL injuries in the United States are estimated to be over half-billion dollars each year (American Orthopaedic Society for Sports Medicine, 2008). A recent meta-analysis conducted on studies from 2010-2013 found that after ACL reconstruction, only 65% of individuals returned to pre-injury level of sport, and only 55% were able to return to competitive sport (Ardern, Taylor, Feller and Webster, 2014). Furthermore, people who have suffered an ACL injury are at increased risk of developing arthritis later on in life, even if they have surgery for the injury (American Orthopaedic Society for Sports Medicine, 2008).

Two studies examined the prevalence of osteoarthritis (OA) in soccer players after sustaining ACL tears. von Porat, Roos and Roos (2004) examined the evidence of OA occurrences 14 years after ACL tear in male soccer players. von Porat et al. found radiographic changes in 78% of the injured knees and 41% had more advanced changes. No differences were seen between surgically or conservatively treated players. Likewise, a similar study examined the prevalence on knee OA in female soccer players 12 years after ACL injury. This study found 82% of the women had radiographic changes in their knee and 51% had more advanced changes. Just over 60% of the players had undergone ACL reconstruction (ACL-R), but surgery was found to have no significant impact on knee symptoms (Lohmander, Östenberg, Englund and Roos, 2004).

A recent report estimates that arthritis may cost the Canadian economy more than
$33 billion annually (The Arthritis Society, 2013). Perhaps, if there was a way to decrease risk of further knee problems such as the development of arthritis, after ACL injury, health care costs could be reduced and patient quality of life would be improved. Prehabilitation has been defined as “the process of increasing functional capacity of an individual to enable them to withstand the stressor of inactivity” (Ditmyer, Topp and Pifer, 2002). However, relatively few studies have examined the effects of preoperative strengthening of the ACL injured patient. The term prehabilitation is not commonly used in the context of ACL injury rehabilitation, but it is commonly applied with other orthopedic procedures including total knee arthroplasty (TKA) (Shaarani, Moyna, Moran and O’Byrne, 2012).

Eitzen, Holm and Risberg (2009) found that two years after ACLR surgery, individuals with preoperative strength deficits of 20% or greater still had abnormal muscular asymmetry. Prolonged quadriceps weakness has been found to contribute to the development of osteoarthritis (OA), which could eventually lead to TKA (Slemenda et al, 1997). If prehabilitation before ACLR was successful, it would improve the rehabilitation process and potentially decrease the patient’s risk of developing OA later in life. OA starts a spiral of pain, swelling, anti-inflammatory medication, activity limitation and eventually TKA.

2.0 Review of Related Literature

Currently there is a limited amount of research in the area of prehabilitation prior to ACL reconstruction. There is even less research looking specifically at prehabilitation and ACLR using hamstring autograft. However, a recent systemic review has concluded that in current literature there are no differences in outcomes between hamstring and
bone-patella-tendon-bone (BPTB) autografts (Spindler et al, 2004). This systemic review noted a small increase in knee laxity and decrease in hamstring strength with a hamstring graft and increased kneeling pain was noted with BPTB graft. It was suggested, based on the current available evidence, that graft choice may not be the primary determinant of successful results after ACLR. Therefore, this literature review includes evidence based on BPTB autografts as well.

After thorough review of the literature by searching Pubmed, Google Scholar and the University of Regina library search engines (Keywords: prehabilitation, isokinetic, ACL, ACL Reconstruction, ACL rehabilitation, ACL deficient knee, Anterior Cruciate Ligament, open kinetic chain, preoperative exercise), to the author’s knowledge there are no studies which use isokinetic exercise to rehabilitate ACL-deficient knees or as prehabilitative exercise prior to ACLR. However, a number of studies have used isokinetic dynamometry for testing and only a few have used isokinetics for rehabilitative exercise post-ACLR. This review looks at current research on quadriceps and hamstring strength pre- and post-ACLR, strength outcomes of prehabilitative exercise programs, significance of measuring patient-relevant outcomes, and isokinetic exercise protocols used for ACLR patients.

2.1 Functional Outcomes Relevant to ACLR Prehabilitation

**Quadriceps and hamstring strength.** It is well documented that quadriceps deficits exist post ACLR. Kobayashi et al. (2004) measured the strength of patients at several intervals following Bone-Tendon-Bone (BTB) ACLR. At one year postoperative, the operated leg still had a 27% deficit in extensors at 60°/sec and 18% deficit at 180°/sec. At 2 years postoperative, there was an 11% deficit in extension at
Flexors had recovered to 90% the strength of the non-surgical leg by six months postoperative. Quadriceps strength recovered more slowly than hamstring strength and patellofemoral pain was found to be a risk factor for the recovery of quadriceps strength. Likewise, Natri et al. (1996) showed extensor strength deficits of 15-20% at 60°/sec and 9-18% at 180°/sec four years post BTB ACLR (p<0.05). Hamstring deficits were not significant. Natri et al. compared an acute group to a chronic group, based on timing receiving ACLR after injury. They found the quadriceps peak torque deficits were greater in the chronic group compared to the acute group. Long-term muscle weakness after ACLR surgery is of great concern since this can contribute to patellofemoral pain, restricted ROM, and the progression of arthritis.

One study evaluated leg strength in ACL deficient knees less than 1 year post-injury. Divir, Eger, Halperin and Shklar (1989) tested ACL deficient knees to examine the dynamic relationship between quadriceps and hamstring muscles, as this ratio is especially important for proper biomechanical function. Patients went to physical therapy for six weeks, which was based on non-isokinetic devices and no particular emphasis on either the quadriceps or hamstrings strength. Isokinetic testing took place approximately eight months after the completion of the program. Divir et al. found a 20% reduction in the mean concentric torque of quadriceps on the injured knee at 30°/sec. Hamstring deficits were not affected. This quadriceps muscle weakness increased the dynamic control ratio on the injured side to be higher than the non-injured side. The dynamic control ratio is hamstring (eccentric)/quadriceps (concentric) and reflects the eccentric capacity of the hamstrings to restrain forward movement of the tibia due to strong contraction of the quadriceps. Eccentric/concentric ratios remained
stable within each muscle, even though the knee is ACL deficient. Divir et al. recommended that ACL deficient knees may benefit from selective conditioning of quadriceps and hamstrings in both concentric and eccentric modes.

To date, few studies have assessed quadriceps strength both pre- and postoperatively in patients undergoing ACLR. Elmqvist et al. (1989) found a 21% deficit in quadriceps peak torque on the injured leg preoperatively and a further 50% decrease in quadriceps strength 14 weeks after reconstruction, both being statistically significant ($p<0.05$). After one year, functional performance was still different between legs, but the surgical leg had surpassed preoperative values and equaled the performance of the uninjured leg preoperatively.

de Jong et al. (2007) evaluated strength and functional capacity before and after BPTB and semitendinosus and gracilis (STG) ACLR to determine the influence of a preoperative strength deficits and other factors, including graft type and gender. de Jong et al. found preoperative quadriceps strength deficits of 17% at 60°/sec and 12% at 180°/sec. At six months postoperative, the quadriceps deficit increased to 36% at 60°/sec and 25% at 180°/sec. Deficits gradually improved to 19% and 16% at 60°/sec and 180°/sec respectively, at 12 months postoperative ($p<0.05$). Deficits were also influenced by graft choice. Patients with BPTB grafts had higher quadriceps deficits and the STG group had increased hamstring deficits. The highest deficits occurred at six months postoperative, with clear improvements until 12 months. de Jong et al. found the deficits at six months to be too high for many of their patients to return to sports/activities, but six months is generally when they are allowed to return to full activities. This is similar to results found by Keays, Bullock-Saxton and Keays (2000),
with very high deficits six months post ACLR. They found patients with lower preoperative quadriceps deficits performed better (limb symmetry index score) at six to nine months postoperative. Perhaps improving quadriceps strength before surgery would result in improved function and reduced deficits post-surgery.

Shelbourne and Johnson (2004) found that patients with preoperative strength >90% of the normal leg had higher postoperative strength (57.5% at one month and 71.6% at three months) compared to patients with poor preoperative strength, <75% of the normal leg (p<0.05). At two-year follow-up, quadriceps strength was the same for all groups. Patients in this study did not follow a preoperative exercise regime and all had BTPB reconstructions. Thus, preoperative quadriceps strength impacts the return of quadriceps muscle strength post ACLR. Early return of quadriceps strength could impact an athlete’s ability to return to sport and the opportunity to regain normal leg strength. Collectively, these results suggest that prehabilitation could potentially play an important role in improving quadriceps strength preoperatively.

A study conducted by Eitzen, Holm and Risberg (2009) also demonstrated the importance of improving quadriceps strength preoperatively. They found that preoperative quadriceps muscle strength deficits had negative consequences for the long-term functional outcome after ACLR (p<0.05). Two years after surgery, individuals with preoperative strength deficits of 20% or greater still had abnormal muscular asymmetry. Eitzen et al. recommended that prehabilitation protocols be used to strengthen the quadriceps and lessen asymmetries to below 20% before ACLR, to reduce the severity of long-lasting postoperative deficits.
**Rehabilitation for ACL Deficient Knees.** Although evidence exists to indicate a need for prehabilitation, few studies have used a prehabititative exercise program to evaluate its effectiveness of improving leg strength and function. Eitzen et al. (2010) used a five-week exercise program for patients with recent (acute) ACL ruptures (within 90 days). The exercise program included intensive muscle strength training, plyometric exercises, and advanced neuromuscular exercises. Participants exercised two to four days per week and completed three to four sets of six to eight repetitions of their prescribed exercises. Exercises included single and multiple joint exercises, open and closed kinetic chain exercises, as well as concentric, eccentric, and isometric strength exercises. Specific single-limb exercises were performed on custom strength training equipment using leg press, leg extension, and leg curl machines. Plyometric exercises included variations of single-leg hops and drills maintaining knee over toe positions, and emphasizing soft landings. Neuromuscular exercises included balance and proprioception activities such as single leg squats on balance pads and BOSU trainers. Perturbation training involved balance and stability exercises on a custom-made roller board, rocker board, and platform. Perturbation of the support surface allows altered forces and torques to be applied to the injured limb in multiple directions in a controlled manner. After the five weeks of training, post-test peak torque values of the injured knee were within normative values (as defined by Phillips, Lo and Mastaglia, 2000) of the dominant limb of healthy subjects ($p<0.05$). Since Eitzen et al. showed the exercise intervention to be so successful at improving knee function in the early stages after ACL injury, they suggest the use of short term intensive exercise as an intervention either
before scheduled ACLR or as preparation of further non-operative management strategies.

Similarly, Tegner et al. (1986) tested patients with chronic ACL deficient knees and found a bilateral quadriceps deficiency of 21% at 30°/sec and 16% at 180°/sec, before undergoing a three month training program for thigh and calf muscles. The training program followed a heavy resistance technique outlined by Delorme (1945). This technique involves 1RM (1 day per week) and 10RM (4 days per week) of isotonic exercises for thigh and calf muscles. After the three months of training, quadriceps deficits reduced to 10% at 30°/sec and 7% at 180°/sec. Due to these significant results ($p<0.05$), Tegner et al. (1986) recommend a strength training program before a patient decides to undertake ACLR.

Keays, Bullock-Saxton, Newcombe and Bullock (2006) designed a six-week home-based physiotherapy program for chronic ACL-deficient patients awaiting ACLR. The program included open and closed kinetic chain quadriceps exercises, balance, functional co-contraction exercises, and muscle control and timing. The goal of strengthening was to improve functional joint stability and reduce the frequency of pivot-shifting episodes. Exercises were to be performed one to two times daily. After the six-week program, the treated ACL-deficient group improved quadriceps strength from 85% to 102% of the uninjured leg at 60°/sec and from 86% to 103% of the uninjured leg at 120°/sec ($p<0.05$). There was no change in the non-treated ACL-deficient group or control group. These patients were not followed up after surgery. The implication of these studies by Eitzen et al. (2010), Tegner et al (1986) and Keays et al. (2006) is that severe quadriceps deficits can be reversed in both chronic and acute ACL deficient
patients. Although it has not been fully explored, prehabilitation strategies could make a significant impact on rehabilitation after ACLR. Furthermore, the limitation of the work by Eitzen et al. (2010) and Keays et al. (2006) is that they did not follow up with patients after surgery to see if the prehabilitative programs made a difference during the rehabilitation process.

**Prehabilitation programs analyzed post-ACLR.** To date, only three published studies have followed up prehabilitated ACLR patients postoperatively with physiological testing. Keays, Bullock-Saxton and Keays (2000) enrolled patients with chronic ACL injuries in a four to six week prehabilitation program and a four-month rehabilitation program after their BPTB ACLR surgeries. Preoperative strength deficits were at 12% for quadriceps at 60°/sec and 9 % at 120°/sec. At six-months postoperatively, there was a 28% deficit in the quadriceps at 60°/sec and 22% at 120°/sec ($p<0.05$). There were no deficits in the hamstrings either pre- or postoperatively. Quadriceps deficits reflect a strength loss of 18% at 60°/sec and 14% at 120°/sec from pre- to post-surgical. Despite this loss in quadriceps strength, functional tests (shuttle run, carioca, side step test, single and triple hop tests) still improved. A major limitation of this study was the failure to include a control group for comparison, and no details of the preoperative exercise program were provided. Because of these limitations, the role of prehabilitative strengthening remains inconclusive.

Shaarani et al. (2013) assigned 20 participants to either control or exercise intervention groups. The exercise group completed a six-week gym and home based exercise intervention. The exercise intervention consisted of four bouts per week; two in the gym and two at home. The program concentrated mainly on lower limb
strengthening, with particular attention to quadriceps and proprioceptive training. The exercise was prescribed in three sets of 12 repetitions with the load being progressed 10-15% per week. The control group was not discouraged to exercise, but were asked to log their exercise, and were not assigned a specific exercise intervention. Physiotherapy was standardized for both groups postoperatively. Following the six-week intervention, single leg hop test scores (improved by 13.5%; \(p<0.05\)), and quadriceps peak torque (improved by 18%; \(p<0.05\)) had increased in the exercise group from baseline. At 12 weeks postoperative, there was no difference in quadriceps peak torque between the control and exercise groups. However, there was a difference between groups for the single leg hop test \((p<0.05)\). The mean time to return to sports was monitored with this study. The control group was 42.5 weeks compared to exercise group, 34.2 weeks. This difference approached statistical significance \((p = .055)\), but from a practical and applied perspective, 8 weeks earlier return to sport demonstrates the importance of such exercises. Limitations of this study include the small sample size and the length of follow-up being limited to 12 weeks.

Kim, Huang, and Park (2015), examined the effects of a four-week preoperative exercise intervention on knee strength and power post-surgery. Kim et al. had 80 male participants randomly assigned to exercise and control groups. Both groups participated in a 12-week postoperative physiotherapy plan, but only the exercise group participated in the four-week preoperative intervention. The preoperative exercise program focused on lower limb strengthening and in particular, on the quadriceps muscles. The program included stationary cycling, open and closed kinetic chain exercises. At three months (12-weeks) post-surgery, the knees extensor strength deficit was 28.5% at 60°/sec and
23.2% at 180°/sec in the exercise group, compared to 36.5% at 60°/sec and 27.9% at 180°/sec in the control group. These differences were statistically significant (p<0.05). The exercise group also showed improvement in single leg hop test scores over the control group (p<0.05).

Two recent studies have used self-reporting questionnaires to document outcomes of prehabilitative exercise programs two years post ACLR. Grindem, Granan, Risberg, Engebretsen, Snyder-Mackler and Eitzen (2015) compared 84 patients undergoing a pre- and postoperative program at a sports medicine clinic to 2690 patients in the Norwegian National Knee Ligament Registry database who received “usual care.” They compared scores from the Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire. Grindem et al. reported that the group who underwent progressive preoperative and postoperative rehabilitation at the sports medicine clinic showed superior patient-reported outcomes both preoperatively and two years postoperatively (p<0.05).

Similarly, Failla et al (2016) compared a group who were treated with extended preoperative rehabilitation, consisting of progressive strengthening and neuromuscular training, to a group who received “usual care.” Failla et al. used the KOOS questionnaire and the International Knee Documentation Committee (IKDC) questionnaire. They found the preoperative exercise group had greater functional outcomes and return to sport rates (72%), when compared to the control group (63%) (p<0.05).

In summary, these studies have consistently shown quadriceps deficits exist before and after ACLR. These studies have also demonstrated that acute and chronic
ACL deficient knees can be rehabilitated to equal strength measures of the uninjured knee before surgical intervention. There is also early evidence to indicate that preoperative exercise programs can impact quadriceps strength and functional outcomes postoperatively. It seems logical and intuitive to assume that if a prehabilitation program can strengthen the knee musculature before surgery, there would be a decreased deficit postoperatively. If the significance of these deficits would be reduced, the rehabilitation process could be improved and potentially re-injury could be prevented.

2.2 Isokinetic Exercise for Prehabilitation prior to ACLR

**Isokinetic exercise program.** To date no studies have used isokinetic exercise to rehabilitate ACL-deficient knees or prehabilitate ACL-deficient knees prior to ACLR. The advantage of isokinetic exercise is that it allows safe exercise at high levels of exertion (since the resistance is never greater than the produced muscular tension), within the full ROM of the joint at a constant velocity (Sherman et al., 1982). However, some researchers have looked at using Open Kinetic Chain (OKC) exercise for both ACL-deficient knees and knees post-ACLR. Tagesson et al. (2008) used an OKC rehabilitation protocol for ACL-deficient patients choosing a conservative, non-operative approach. OKC exercises in this study were not isokinetic, but isotonic. At the four-month follow-up, the OKC group had improved isokinetic quadriceps strength over the Closed Kinetic Chain (CKC) group at 60°/sec (p<0.05). A similar study by Mikkelsen, Werner and Eriksson (2000) looked at the use of OKC rehabilitation protocols post-ACLR. For this study, isokinetic concentric and eccentric OKC exercise was used starting six weeks postoperative. At six-months postoperative, patients in the group that trained with both OKC + CKC exercises had better quadriceps torque at all speeds than
the group that performed only CKC exercises. At six months postoperative, none of the patients in this study had fully regained their quadriceps strength, but 12 of the 22 patients in the OKC + CKC exercise group were able to return to the same level of sports and activity as before they were injured. OKC exercise is evidently effective even in ACL deficiency, and several studies have indicated a correlation between pre- and postoperative quadriceps strength, further illustrating the benefit of OKC exercise as a prehabilitation strategy prior to ACLR. This limited but encouraging research could be an important step in improving function and strength postoperatively.

Another recent study examined the use of isokinetic exercise for rehabilitation post-ACLR. Fabiś (2007) evaluated the peak torque of knee extensors and flexors at 12 and 24-weeks post ACLR with hamstring autograft. From 12 to 24-weeks post-surgery, participants followed an isokinetic exercise program. They exercised for 20 minutes at 240°/sec for the first six weeks and at 180°/sec for the following six weeks. At 12-weeks postoperative, the mean deficit of quadriceps peak torque was 38% and hamstring was 25.2%. Following isokinetic training, the quadriceps peak torque deficit was reduced by 23.8% for quadriceps and 20.7% for hamstrings. Although both deficit reductions were statistically significant ($p<0.05$), the reduction in quadriceps deficit was higher. Fabiś recommended that isokinetic measurement ought to become standard procedure for evidence based monitoring of the rehabilitation process in patients with ACLR.

### 3.0 Purpose and Significance of the Study

The purpose of this study was to investigate the effectiveness of an isokinetic exercise program for prehabilitation prior to ACLR and evaluate the significance of the effects before and after surgery. The use of an isokinetic exercise program would
specifically target the quadriceps and hamstrings around the injured knee, and allow the patient to exercise/train safely at a high intensity.

There are a few published randomized control trials using a prehabilitative exercise program prior to ACLR and following patients afterwards to examine if the prehabilitation program made a difference in the rehabilitation process. However, none of these studies have used isokinetic exercise as part of the prehabilitation program. A few studies followed up with participants at 12 weeks postoperative (Kim, Huang, Park, 2015; Shaarani et al. 2013). Only one study followed up at six months postoperative (Keays, Bullock-Saxton and Keays, 2000), but did not have a control group. A few studies have followed up with participants at two years postoperative, but these studies have used self-reporting only, and no physiological measurements (Failla et al. 2016; Grindem et al. 2015). By attempting to address some of the gaps, the present study contributes to the body of knowledge regarding the effectiveness of prehabilitation programs in orthopaedics.

Prehabilitation has the potential to improve patient function, improve the rehabilitation process and prevent the progression of OA. Prehabilitation could potentially reduce health care costs by allowing patients to return to activity or sport quicker, and by preventing further treatments and surgeries due to the progression of OA. Currently prehabilitation in orthopaedics is a relatively new and unexplored area of research. This study explores the impact of prehabilitation exercise both pre- and post-ACLR, an area of limited evidence.
4.0 Hypotheses

H1: Isokinetic exercise will result in increased quadriceps peak torque in the exercise group when compared to the control group before ACLR.

H2: Improved strength before surgery will result in higher peak torque at 24-weeks postoperative in the exercise group when compared to control group.

H3: The exercise group will have improved functional measures at 24-weeks postoperative compared to the control group.

5.0 Methods

This research study utilized the classic two-group (intervention and control) pre-test post-test experimental design with random assignment to address the hypotheses. Both groups were assessed at baseline (before treatment), 8-weeks (end of treatment, before surgery), and 24-weeks postoperative. This approach will objectively determine if differences between the two groups exist at several time intervals. This experimental design was chosen to determine causal relationships from the intervention. The control group did not receive the isokinetic exercise training treatment, which decreases threats to internal validity and helps determine causal relationships from the isokinetic treatment (Creswell, 2009). This randomized control trial compared leg strength and functional measures among patients scheduled to receive ACLR.

5.1 Sample

This study was conducted on an equal size of exercise ($n = 9$) and control ($n = 9$) participants. Stratified random assignment ensured equal men and women in each group. All participants were scheduled for ACLR surgery and received an autograft (hamstring). All participants were patients of the same surgeon and were referred to the study by that
surgeon. Participants were excluded if they had previous knee surgeries (on either knee), previous injury to the non-surgical side, the surgical knee was locked or had decreased ROM, involvement of other ligaments of the knee, significant edema, serious contraindications to exercise, or were taking drugs or supplements that may influence muscle mass and/or recovery. Participants were all recreational athletes or had physically demanding occupations.

5.2 Instrumentation

**Isokinetic testing.** Quadriceps and hamstring strength (peak torque ft-lbs) is measured using an isokinetic dynamometer (Cybex 6000, Ronkonkoma, New York or CSMI HUMAC Norm, Stoughton, Massachusetts). The isokinetic dynamometer is a machine that measures foot-pounds (ft-lbs) of torque and must be calibrated to ensure accuracy. The calibration procedure is based on the principle that a quantity of weight on the input arm, set to a specific length, will generate a known amount of torque when it falls. During calibration, 100lbs is dropped with the input arm set at 18 inches and following the drop, the system adjusts its internal look-up table. It is recommended that the weight verification procedure be performed monthly and a full weight calibration procedure be performed quarterly (CYBEX Division of LUMEX, Inc., New York, 1991). The dynamometer’s computer tracks calibration and verification procedures.

Isokinetic testing measures peak torque, peak torque as a percent of body weight (%BW) and hamstring/quadriceps ratio. Normative data (at speed of 60°/sec) suggest the hamstring/quadriceps (HQ) ratio should be 50-70% (mean 63%) for both men and women. Quadriceps peak torque as a %BW should be 80-100% (mean 85%) for men and 60-80% (mean 73%) for women. Hamstring peak torque as a %BW for men should
be 45-60% (mean 52%) and for women should be 40-50% (mean 45%). (Rankin and Thompson, 1983).

Applying isokinetic testing to ACL-deficient knees, Kannus (1988) indicates that the HQ ratio in the chronic ACL-deficient knee is higher than the HQ ratio in the uninjured knee due to quadriceps muscle weakness. This is especially evident at higher speeds (180°/sec). The same study found that long-term outcomes were better in subjects with less than 15% difference in HQ ratio between the injured and uninjured knees (p<0.05). Kannus (1988) suggests that an optimal HQ ratio for an ACL-deficient knee is likely the HQ ratio of the uninvolved knee.

Patten Wyatt and Edwards (1981) suggested that isokinetic testing should be performed at slow, medium, and fast speeds (60°/sec, 180°/sec and 300°/sec), for both quadriceps and hamstrings. The purpose of this recommendation is to observe torque differences and ratio differences at the various speeds. In particular, the 300°/sec speed is recommended since the knee extends at a rate of 233°/sec while the quadriceps is firing in the terminal swing phase of the gait cycle. Also, at 300°/sec, the hamstring to quadriceps ratio reaches unity.

Zemach, Almoznino, Barak and Dvir (2009) recommend using one to two testing speeds, specific to the patient group. This way a speed can be selected that will be well tolerated by the patient, rather than using low speeds that could increase joint pain, or high speeds which may not give accurate results. They recommend using both eccentric and concentric testing modes to determine a functional ratio.

Recent studies from Eitzen et al (2009 and 2010), and Kim et al (2015), looking at ACL-deficient and ACL reconstructed knees used testing speeds of 60°/sec and

For this study, testing speeds of 60°/sec, 120°/sec and 180°/sec were used. Data collected at 60°/sec is comparative to normative data to ensure the non-operative leg is within normative ranges. The 120°/sec and 180°/sec speeds are well tolerated for the ACL deficient knee and allow a comparison of torque values to the slower speed and to monitor quadriceps/hamstring ratio increases. At all speeds, the injured knee was compared to the uninjured knee to observe deficits and differences in the quadriceps/hamstring ratio. All testing speeds were also used in the exercise program.

5.3 Procedures

Baseline testing was performed eight weeks before surgery. Demographic and anthropometric information for all patients was collected including: age, sex, BMI, duration of knee injury, current exercise and physical activity, previous injuries to the uninvolved leg, other medical history and medications. Physical Activity level was ranked as average, < average, average or > average when compared to current Canadian Society for Exercise Physiology (CSEP) activity recommendations. CSEP recommends 150 minutes of moderate to vigorous aerobic exercise per week and strength training exercises 2 times per week for adults 18-64 years old (www.csep.ca/guidelines). Resting heart rate and blood pressure was measured to ensure patients are safely within CSEP’s guidelines to begin an exercise program (BP ≤ 144/94 mmHg and HR ≤ 100b·min⁻¹). Baseline testing was performed, and then patients were randomly assigned to the isokinetic exercise group or control group.
The prehabilitation exercise program involved eight weeks of isokinetic, concentric exercise three times per week on non-consecutive days (as much as possible), for the isokinetic exercise group. Participants completed isokinetic exercise after a 10 minute warm-up on an upright cycle ergometer (Monark 839e, Sweden). The isokinetic, concentric training protocol involved 10 repetitions at the following speeds: 60°/sec, 90°/sec, 120°/sec, 150°/sec, 180°/sec for the first four weeks. For the last four weeks, more sets were added to the isokinetic exercise program: 60°/sec, 90°/sec, 120°/sec, 150°/sec, 180°/sec, 150°/sec, 120°/sec, 90°/sec, and 60°/sec. Each speed exercised both extensors and flexors with a 30 second rest between sets. All participants used the antishear device for training and only the surgical leg was exercised. ROM was set from 0-90°. All participants, both in the control and exercise groups, were encouraged to maintain their current exercise programs, but no additional exercises were assigned.

All participants were scheduled for ACLR immediately following the eight week assessment/training. Participants all attended the same physical therapy centre and followed the “usual care” guidelines (including cold therapy treatment with Cold Rush or Cryocuff systems), and postoperative physical therapy treatment program as outlined by the referring surgeon. All participants were tested again at 24-weeks (six-months) postoperative. At 24-weeks postoperative, the Single Leg Hop test for distance was included to measure the functional outcome of the rehabilitative process.

**Data collection procedures.** Participants were scheduled for two preoperative data collection points: baseline (T1), and 8-weeks (T2), and one postoperative data collection point scheduled at 24-weeks (T3). At each assessment interval, testing protocols were delivered in the same order. Testing began with anthropometric and
demographic data collection, followed by a 10 minute warm-up of upright cycling, and isokinetic testing on both knees. At 24-weeks postoperative, the addition of the Single Leg Hop test for distance was included. This test was added at the end of all previous tests. Time was allowed to recover from isokinetic testing, but the participant was still sufficiently warmed up.

Isokinetic testing was performed on both groups using an isokinetic dynamometer (Cybex 6000, Ronkonkoma, New York or CSMi HUMAC Norm, Stoughton, Massachusetts). The participant was seated upright with hips bent at 90°. The rotational point of dynamometer arm was lined up with rotational point of the knee. The participant was strapped down at the hips and proximal to the knee joint to ensure focused movement at the knee. The participant’s torso was braced by a seatbelt and they grasped handles at the sides of the seat to assist in securing the hips. The movement arm was strapped to the leg proximal to the ankle and distal to the tibial tuberosity using the antishear device. The uninjured limb was always tested first. Approximately 0-90° ROM was tested. The isokinetic testing protocol used to test concentric strength was: four trial reps and five testing reps at 60°/sec, four trial reps and five testing reps at 120°/sec and four trial reps and 15 testing reps at 180°/sec. Participants received verbal encouragement to “kick” and “pull” as hard as possible during the testing repetitions. Testing was corrected for maximum gravitational effect (MAX GET). Variance was recorded and patients were retested if variance exceeded 10%. The highest peak torque of extension and flexion was used for analysis. Body mass (lbs.) was measured at all assessments so isokinetic data could be corrected for any body mass changes.
The single leg hop test for distance was performed as described by Daniel et al. (1982). With shoes on, the participant stands on one leg (the leg being tested), hops as far as possible, and lands controlled on the same leg (landing maintained for two seconds). The distance hopped (measured from the great toe), is recorded to the nearest centimeter. Participants complete one practice trial and three measured and recorded trials on each leg. Each test begins by testing the non-operative limb. Trials were repeated if the participant was unable to maintain the landing or did not execute the hop successfully. The highest values were recorded and used to calculate the Limb Symmetry Index (LSI) which is used for statistical analysis. LSI is calculated using the following formula: (distance for operative leg/distance for non-operative leg) x 100.

5.4 Data Analysis Strategy

Data were input, verified and analyzed by IBM SPSS 24.0 (Chicago, IL). Descriptive analysis began with normality tests and analysis for outliers. Demographic information was assessed between groups using independent t-tests to ensure no statistical differences between groups. Mann-Whitney U test was used to compare ordinal level data on aerobic and strength activity levels between groups to ensure no statistical differences.

A 2x3 (group x time) mixed-model analysis of variance (ANOVA) was run at each velocity for quadriceps and hamstrings. If statistically significant, these ANOVAs were followed up with paired-samples t-tests to examine peak torque changes over the three different time periods within each group. These tests were followed by two 2x2 ANOVAs which serve as interaction contrasts, examining the interaction between Time and Group for the baseline to eight week (pre-surgical) time period, and the baseline to
24-week (post-surgical) time period. These interaction contrasts were followed by an independent t-test to compare peak torque between the two groups at 24-weeks (postoperative).

An independent t-test was used to compare the single leg hop test scores between groups. Alpha was set at $p \leq 0.05$ for all statistical analysis.

6.0 Results

6.1 Demographics

Of the 22 participants recruited, only 20 completed the study. One participant was scheduled for surgery too early for the study protocols and one participant decided not to receive surgery. Of the 20 that completed the study, one participant decided on a different surgery (allograft instead of autograft) and one participant’s data could not be used due to variability in the test results. The final data set had nine participants in each group.

As seen in Table 1, there were no statistically significant differences for age, Body Mass Index (BMI) and time since injury between control and exercise participants. As seen in Table 2, Mann–Whitney U tests revealed no statistically significant differences in aerobic or strength physical activity levels between the control and exercise groups.
<table>
<thead>
<tr>
<th>Participant Information</th>
<th>Participant Group</th>
<th>Mean ± Standard Deviation</th>
<th>95% CI LL-UL</th>
<th>T-test for equality of Means t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>Control (n=9)</td>
<td>30.0 ± 11.8</td>
<td>[-4.61, 14.39]</td>
<td>1.133</td>
<td>.28</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>25.1 ± 5.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>Control (n=9)</td>
<td>26.6 ± 3.5</td>
<td>[-4.28, 4.06]</td>
<td>.055</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>26.8 ± 4.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time since Injury (months)</td>
<td>Control (n=9)</td>
<td>22.4 ± 39.4*</td>
<td>[-12.23, 48.34]</td>
<td>1.372</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>4.3 ± 2.9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: CI= confidence interval; LL= lower limit; UL=upper limit.
BMI = Body Mass Index
* large SD was due to two participants
Table 2
Aerobic and Strength Physical Activity Levels between groups

<table>
<thead>
<tr>
<th>Participant information</th>
<th>Participant Group</th>
<th>Mann-Whitney U</th>
<th>z value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aerobic activity level</strong></td>
<td>Control ($Md=2$, $n=9$)</td>
<td>27</td>
<td>-1.30</td>
<td>.19</td>
</tr>
<tr>
<td></td>
<td>Exercise ($Md=1$, $n=9$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Strength activity level</strong></td>
<td>Control ($Md=2$, $n=9$)</td>
<td>38</td>
<td>-.24</td>
<td>.81</td>
</tr>
<tr>
<td></td>
<td>Exercise ($Md=2$, $n=9$)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Analysis of Baseline Measurements. As shown in Table 3, no statistically significant differences were found between groups when comparing baseline peak torque measurements of the quadriceps and hamstring muscles at three different velocities of muscle contraction.
Table 3
Initial Baseline (Week 0) Peak Torque (ft-lbs) Measurements of Participants.

<table>
<thead>
<tr>
<th>Participant Information</th>
<th>Participant Group</th>
<th>Mean ± Standard Deviation</th>
<th>95% CI LL-UL</th>
<th>T-test for equality of Means t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Torque Quads 60°/sec</td>
<td>Control (n=9)</td>
<td>109.7 ± 45.6</td>
<td>[51.78, 42.44]</td>
<td>.210</td>
<td>.84</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>114.3 ± 48.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Torque Hamstrings 60°/sec</td>
<td>Control (n=9)</td>
<td>58.4 ± 27.3</td>
<td>[-33.32, 24.07]</td>
<td>.344</td>
<td>.74</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>63.0 ± 28.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Torque Quads 120°/sec</td>
<td>Control (n=9)</td>
<td>83.7 ± 29.0</td>
<td>[-41.67, 24.78]</td>
<td>.539</td>
<td>.60</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>92.2 ± 37.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Torque Hamstrings 120°/sec</td>
<td>Control (n=9)</td>
<td>50.1 ± 21.5</td>
<td>[-28.29, 18.74]</td>
<td>.431</td>
<td>.67</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>54.9 ± 25.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Torque Quads 180°/sec</td>
<td>Control (n=9)</td>
<td>69.8 ± 20.0</td>
<td>[-34.48, 15.59]</td>
<td>.800</td>
<td>.44</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>79.2 ± 29.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Torque Hamstrings 180°/sec</td>
<td>Control (n=9)</td>
<td>46.6 ± 18.2</td>
<td>[-22.03, 18.92]</td>
<td>.161</td>
<td>.87</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>48.1 ± 22.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: CI= confidence interval; LL= lower limit; UL=upper limit.
6.2 Outcome Measures

**Analysis of quadriceps peak torque at 60°/sec.** A 2x3 mixed model ANOVA was conducted to compare mean quadriceps peak torque (ft-lbs) values between groups (exercise vs control) over the three testing intervals; baseline, 8-week (pre-surgical) and 24-week (post-surgical). The mean and standard deviation for quadriceps measured at 60°/sec are presented in **Table 4**. Within-subject effects indicated a statistically significant main effect for time, $F(2,32) = 7.76, p = .002, \eta^2_p = .33$, and a statistically significant interaction for time x group, $F(2,32) = 4.68, p = .016, \eta^2_p = .23$. These results indicate not only changes in values over time, but also differences in peak torque values between the groups over time. These differences are illustrated in **Figure 1**. There was a not a statistically significant between-subjects effect for group, $F(1,16)= 3.26, p =.09, \eta^2_p = .17$. 
Table 4
Quadriceps Peak torque (ft-lbs) measured at 60°/sec.

<table>
<thead>
<tr>
<th>Participant Information</th>
<th>Participant Group</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Quadriceps Peak Torque 60°/sec</td>
<td>Control (n=9)</td>
<td>109.7 ± 45.6</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>114.3 ± 48.7</td>
</tr>
<tr>
<td>8 week (pre-surgical) Quadriceps Peak Torque 60°/sec</td>
<td>Control (n=9)</td>
<td>112.3 ± 32.7</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>151.2 ± 38.0</td>
</tr>
<tr>
<td>24 week (post-surgical) Quadriceps Peak Torque 60°/sec</td>
<td>Control (n=9)</td>
<td>84.1 ± 16.2</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>127.3 ± 37.9</td>
</tr>
</tbody>
</table>
Figure 1: Mean ± SD Quadriceps Peak Torque at 60°/sec.
Paired-samples t-tests were conducted to evaluate the quadriceps peak torque change over time for each group. For the control group, there were no statistically significant changes from baseline measurements ($M = 109.67, SD = 45.55$) to 8-week (pre-surgical) measurements ($M = 112.33, SD = 32.66$), $t(8)= .417, p = .69$, or to the 24-week (post-surgical) measurements ($M = 84.11, SD = 16.17$), $t(8)= 1.89, p = .10$. There was, however, a statistically significant change when comparing the eight week pre-surgical measurements to the 24-week, post-surgical measurements, $t(8)= 3.37, p = .01$. The mean decrease in peak torque was 28.22 ft-lbs, 95% CI [8.90, 47.55].

Pair-samples t-tests on the exercise group indicate a statistically significant change for peak torque from baseline ($M = 114.33, SD = 48.69$) to eight week pre-surgical measurement ($M = 151.22, SD = 37.97$), $t(8)= 4.05, p = .004$. The mean increase in peak torque was 36.89 foot-pounds, 95% CI [-57.87, -15.91]. There was no statistically significant change for peak torque from baseline to 24 week post-surgical measurement ($M = 127.33, SD = 37.91$), $t(8)= 1.11, p = .30$. There was a statistically significant change when comparing eight week pre-surgical measurement to 24 week post-surgical measurement, $t(8)= 3.11, p = .014$. The mean decrease in peak torque was 23.89 foot-pounds, 95% CI [6.17, 41.61].

A 2x2 mixed model ANOVA analyzing baseline measures and eight week pre-surgical measures of quadriceps at 60°/sec, served as an interaction contrast of the exercise intervention at these two time periods. The interaction contrast was statistically significant for time x group $F(1,16) = 9.48, p = .007, \eta^2_p = .38$. 
Similarly, a 2x2 mixed model ANOVA served as an interaction contrast between groups from baseline measurements to 24 weeks post-surgical. The interaction contrast was statistically significant, $F(1,16) = 4.66, p = .046, \eta_p^2 = .23$.

Finally, an independent t-test compares differences in quadriceps peak torque at 60°/sec between the two groups at 24 weeks post-surgery. There was a statistically significant difference in peak torque between control ($M = 84.11, SD = 16.17$) and exercise groups ($M = 127.33, SD = 37.91$), $t(16)= 3.14, p = .009$. The mean difference was 43.22 foot-pounds, 95% CI [-73.53, – 12.92].

**Analysis of quadriceps peak torque at 120°/sec.** A 2x3 mixed model ANOVA was conducted to compare mean quadriceps peak torque values between groups over the three testing intervals. Mean and standard deviation for quadriceps measured at 120°/sec are presented in Table 5. Within-subject effects indicated a statistically significant main effect for time, $F(2,32) = 12.61, p < .001, \eta_p^2 = .44$, and a statistically significant interaction effect for time x group, $F(2,32) = 4.80, p = .015, \eta_p^2 = .23$. These results indicate changes in values over time, and also differences in peak torque values between the groups over time. These differences are illustrated in Figure 2. The between-subjects main effect for group was not statistically significant, $F(1,16) = 3.66, p = .074, \eta_p^2 = .19$. 
Table 5
Quadriceps Peak Torque (ft-lbs) Measured at 120°/sec.

<table>
<thead>
<tr>
<th>Participant Information</th>
<th>Participant Group</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Quadriceps Peak Torque 120°/sec</td>
<td>Control (n=9)</td>
<td>83.8 ± 29.0</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>92.2 ± 37.0</td>
</tr>
<tr>
<td>8 week (pre-surgical) Quadriceps Peak Torque 120°/sec</td>
<td>Control (n=9)</td>
<td>92.3 ± 31.8</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>131.9 ± 40.6</td>
</tr>
<tr>
<td>24 week (post-surgical) Quadriceps Peak Torque 120°/sec</td>
<td>Control (n=9)</td>
<td>72.3 ± 18.3</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>106.7 ± 37.4</td>
</tr>
</tbody>
</table>
Figure 2: Mean ± SD Quadriceps Peak Torque at 120°/sec
Paired-samples t-tests were conducted to evaluate the quadriceps peak torque change at 120°/sec over time for each group. For the control group, there were statistically significant changes from baseline ($M = 83.78, SD = 28.97$) to 8-week (pre-surgical) measurement ($M = 92.33, SD = 31.84$), $t(8)= 2.63, p = .03$. The mean increase in peak torque was 8.55 ft-lbs, 95% CI [-16.06, -1.05]. There was no statistically significant change from baseline to 24-week (post-surgical) measurement ($M = 72.33, SD = 18.34$), $t(8)= 1.46, p = .18$. There was also a statistically significant decrease when comparing the 8-week pre-surgical measurement to the 24-week post-surgical measurement, $t(8)= 2.35, p = .046$. The mean decrease in peak torque was 20 ft-lbs, 95% CI [.40, 39.60].

Pair-samples t-tests on the exercise group data indicated a statistically significant increase in peak torque from baseline ($M = 92.22, SD = 37.03$) to 8-week pre-surgical measurement ($M = 131.89, SD = 40.57$), $t(8)= 4.59, p = .002$. The mean increase in peak torque was 39.67 ft-lbs, 95% CI [-59.58, -19.76]. There was no statistically significant change from baseline to 24 week post-surgical measurement ($M = 106.67, SD = 37.35$), $t(8)= 1.51, p = .17$. There was a statistically significant change when comparing 8-week pre-surgical measurement to 24-week post-surgical measurement, $t(8)= 4.15, p = .003$. The mean decrease in peak torque was 25.22 ft-lbs, 95% CI [11.20, 39.24].

A 2x2 mixed model ANOVA analyzing baseline measures and 8-week pre-surgical measures of quadriceps at 120°/sec, served as an interaction contrast of the exercise intervention at these two time periods. The interaction contrast of time by group was statistically significant, $F(1,16) = 11.37, p = .004, \eta^2_p = .42$. 
Similarly, a 2x2 mixed model ANOVA was used to examine the interaction contrast between groups from baseline to 24-weeks post-surgical measurements. The interaction contrast approached statistical significance, $F(1,16) = 4.38, p = .053, \eta^2_p = .22$.

An independent t-test compared the differences in quadriceps peak torque at 120°/sec between the two groups at 24-weeks post-surgery. There was a statistically significant difference in peak torque between the control ($M = 72.33, SD = 18.34$) and exercise group ($M = 106.67, SD = 37.35$), $t(16) = 2.48, p = .025$. The mean difference was 34.33 ft-lbs, 95% CI [-63.74, −4.93].

**Analysis of quadriceps peak torque at 180°/sec.** A 2x3 mixed model ANOVA was conducted to compare mean quadriceps peak torque values between groups over the three testing intervals. Mean and standard deviation for quadriceps measured at 180°/sec are presented in Table 6. Within-subject effects indicated a statistically significant main effect for time, $F(2,32) = 8.55, p = .001, \eta^2_p = .35$. The interaction effect for time by group approached statistical significance, $F(2,32) = 3.10, p = .059, \eta^2_p = .16$. These differences are illustrated in Figure 3. These results indicate changes in values over time, but no statistically significant differences in peak torque values between the groups over time. The between-subjects main effect for group was not statistically significant, $F(1,16) = 4.01, p = .063, \eta^2_p = .20$. 
Table 6
Quadriceps Peak Torque (ft-lbs) Measured at 180°/sec.

<table>
<thead>
<tr>
<th>Participant Information</th>
<th>Participant Group</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Quadriceps Peak Torque 180°/sec</td>
<td>Control (n=9)</td>
<td>69.8 ± 19.9</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>79.2 ± 29.3</td>
</tr>
<tr>
<td>8 week (pre-surgical) Quadriceps Peak Torque 180°/sec</td>
<td>Control (n=9)</td>
<td>75.8 ± 26.4</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>106.1 ± 32.5</td>
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<tr>
<td>24 week (post-surgical) Quadriceps Peak Torque 180°/sec</td>
<td>Control (n=9)</td>
<td>63.1 ± 12.2</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>88.8 ± 27.4</td>
</tr>
</tbody>
</table>
**Figure 3** Mean ± SD Quadriceps Peak Torque 180°/sec
Paired-samples t-tests were conducted to evaluate the quadriceps peak torque changes at 180°/sec over time for each group. For the control group, there were no statistically significant changes from baseline measurement ($M = 69.78$, $SD = 19.95$) to 8-week (pre-surgical) measurement ($M = 75.78$, $SD = 26.37$), $t(8) = 1.90$, $p = .09$, or to 24-week (post-surgical) measurements ($M = 63.11$, $SD = 12.19$), $t(8) = 1.0$, $p = .35$. There was also no statistically significant difference when comparing the 8-week pre-surgical measurement to the 24-week post-surgical measurement, $t(8) = 1.65$, $p = .14$.

Pair-samples t-tests on the exercise group indicate statistically significant changes from baseline peak torque ($M = 79.22$, $SD = 29.28$) to 8-week pre-surgical measurement ($M = 106.11$, $SD = 32.47$), $t(8) = 4.19$, $p = .003$. The mean increase in peak torque was 26.89 ft-lbs, 95% CI [-41.67, -12.11]. There was no statistically significant change from baseline to 24-week post-surgical measurement ($M = 88.78$, $SD = 27.41$), $t(8) = 1.26$, $p = .24$. There was a statistically significant change when comparing 8-week pre-surgical measurement to 24-week post-surgical measurement, $t(8) = 3.88$, $p = .005$. The mean decrease in peak torque was 17.33 ft-lbs, 95% CI [7.04, 27.62].

A 2x2 mixed model ANOVA analyzing baseline measures and 8-week pre-surgical measures of quadriceps at 180°/sec served as an interaction contrast of the exercise intervention at these two time periods. The interaction contrast of time by group was statistically significant, $F(1,16) = 8.55$, $p = .01$, $\eta^2_p = .35$. Similarly, a 2x2 mixed model ANOVA was used to examine the interaction contrast between groups from baseline to 24-weeks post-surgical measurement. The interaction contrast was not statistically significant, $F(1,16) = 2.57$, $p = .13$, $\eta^2_p = .14$.  

An independent t-test compares the differences in quadriceps peak torque at 180°/sec between the two groups at 24-weeks post-surgery. There was a statistically significant difference in peak torque between control (M = 63.11, SD = 12.19) and exercise groups (M = 88.78, SD = 27.41), \( t(16) = 2.57, p = .021 \). The mean difference was 25.67 ft-lbs, 95% CI [-46.87, – 4.47].

**Analysis of hamstrings peak torque at 60°/sec.** A 2x3 mixed model ANOVA was conducted to compare mean hamstrings peak torque values between groups over the three testing intervals; baseline, 8 week (pre-surgical) and 24 week (post-surgical). The mean and standard deviation for hamstrings measured at 60°/sec are presented in Table 7. Within-subject effects indicated a statistically significant main effect for time, \( F(2,32) = 10.33, p < .001, \eta^2_p = .39 \), but no statistically significant interaction effect for time x group, \( F(2,32) = 3.11, p = .059, \eta^2_p = .16 \). These results indicate changes in values over time, but no statistically significant differences in peak torque values between the groups over time. The between-subjects interaction for group was not statistically significant, \( F(1,16)= 2.33, p = .15, \eta^2_p = .13 \).

A 2x2 mixed model ANOVA analyzing baseline measures and 8-week pre-surgical measures of hamstrings at 60°/sec, served as an interaction contrast of the exercise intervention at these two time periods. The interaction contrast approached statistical significance for time x group, \( F(1,16) = 4.27, p = .055, \eta^2_p = .21 \).
Table 7
Hamstrings Peak Torque (ft-lbs) measured at 60°/sec.

<table>
<thead>
<tr>
<th>Participant Information</th>
<th>Participant Group</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline Hamstrings Peak Torque 60°/sec</strong></td>
<td>Control ($n=9$)</td>
<td>58.2 ± 25.5</td>
</tr>
<tr>
<td></td>
<td>Exercise ($n=9$)</td>
<td>63.0 ± 28.1</td>
</tr>
<tr>
<td><strong>8 week (pre-surgical) Hamstrings Peak Torque 60°/sec</strong></td>
<td>Control ($n=9$)</td>
<td>66.4 ± 18.4</td>
</tr>
<tr>
<td></td>
<td>Exercise ($n=9$)</td>
<td>87.0 ± 20.4</td>
</tr>
<tr>
<td><strong>24 week (post-surgical) Hamstrings Peak Torque 60°/sec</strong></td>
<td>Control ($n=9$)</td>
<td>54.1 ± 20.4</td>
</tr>
<tr>
<td></td>
<td>Exercise ($n=9$)</td>
<td>75.0 ± 25.2</td>
</tr>
</tbody>
</table>
Analysis of hamstrings peak torque at 120°/sec. A 2x3 mixed model ANOVA was conducted to compare mean hamstrings peak torque values between groups over the three testing intervals. Mean and standard deviation for hamstrings measured at 120°/sec are presented in Table 8. Within-subject effects indicated a statistically significant main effect for time, $F(2,32) = 4.92, p = .014, \eta^2_p = .24$, but no statistically significant interaction effect for time x group was found, $F(2,32) = 2.78, p = .077, \eta^2_p = .15$. These results indicate changes in values over time, but no statistically significant differences in peak torque values between the groups over time. The between-subjects main effect for group was not statistically significant, $F(1,16) = 2.33, p = .15, \eta^2_p = .13$.

A 2x2 mixed model ANOVA analyzing baseline and 8-week pre-surgical measurement of hamstrings at 120°/sec, served as an interaction contrast of the exercise intervention at these two time periods. The interaction contrast was statistically significant for time x group, $F(1,16) = 4.98, p = .04, \eta^2_p = .24$. 
Table 8
Hamstrings Peak Torque (ft-lbs) measured at 120°/sec.

<table>
<thead>
<tr>
<th>Participant Information</th>
<th>Participant Group</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Hamstrings Peak Torque 120°/sec</td>
<td>Control (n=9)</td>
<td>50.1 ± 21.5</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>54.9 ± 25.4</td>
</tr>
<tr>
<td>8 week (pre-surgical) Hamstrings Peak Torque</td>
<td>Control (n=9)</td>
<td>53.0 ± 18.8</td>
</tr>
<tr>
<td>120°/sec</td>
<td>Exercise (n=9)</td>
<td>75.1 ± 21.6</td>
</tr>
<tr>
<td>24 week (post-surgical) Hamstrings Peak Torque</td>
<td>Control (n=9)</td>
<td>49.8 ± 16.2</td>
</tr>
<tr>
<td>120°/sec</td>
<td>Exercise (n=9)</td>
<td>65.0 ± 25.1</td>
</tr>
</tbody>
</table>
Analysis of hamstrings peak torque at 180°/sec. A 2x3 mixed model ANOVA was conducted to compare mean hamstrings peak torque values between groups over the three testing intervals. Mean and standard deviation for hamstrings measured at 180°/sec are presented in Table 9. Within-subject effects indicated a statistically significant main effect for time, $F(2,32) = 3.48, p = .043, \eta^2_p = .18$, and a statistically significant interaction effect for time x group, $F(2,32) = 3.53, p = .041, \eta^2_p = .18$. These results indicate changes in values over time and statistically significant differences in peak torque values between the groups over time. These differences are illustrated in Figure 4. The between-subjects main effect for group was not statistically significant, $F(1,16) = 1.61, p = .22, \eta^2_p = .09$. 
Table 9
Hamstrings Peak Torque (ft-lbs) measured at 180°/sec.

<table>
<thead>
<tr>
<th>Participant Information</th>
<th>Participant Group</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Hamstrings Peak Torque 180°/sec</td>
<td>Control (n=9)</td>
<td>46.6 ± 18.2</td>
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<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>48.1 ± 22.5</td>
</tr>
<tr>
<td>8 week (pre-surgical) Hamstrings Peak Torque 180°/sec</td>
<td>Control (n=9)</td>
<td>46.4 ± 16.4</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>65.1 ± 19.7</td>
</tr>
<tr>
<td>24 week (post-surgical) Hamstrings Peak Torque 180°/sec</td>
<td>Control (n=9)</td>
<td>47.2 ± 8.3</td>
</tr>
<tr>
<td></td>
<td>Exercise (n=9)</td>
<td>57.4 ± 23.1</td>
</tr>
</tbody>
</table>
Figure 4: Mean ± SD Hamstring Peak Torque at 180°/sec
Paired-samples t-tests were conducted to evaluate the hamstrings peak torque change over time for each group. For the control group, there were no statistically significant changes from baseline measurement ($M = 46.56, SD = 18.2$) to 8-week (pre-surgical) measurement ($M = 46.44, SD = 16.39$), $t(8) = .055, p = .96$, or from baseline to 24-week (post-surgical) measurement ($M = 47.22, SD = 8.33$), $t(8) = .123, p = .91$. There were no statistically significant differences indicated when comparing the 8-week pre-surgical measurements to the 24-week, post-surgical measurement, $t(8) = .158, p = .88$.

Paired-samples t-tests on the exercise group indicate statistically significant changes from baseline peak torque measurement ($M = 48.11, SD = 22.54$) to 8-week pre-surgical measurement ($M = 65.11, SD = 19.73$), $t(8) = 3.23, p = .012$. The mean increase in peak torque was 17.0 ft-lbs, 95% CI [-29.13, -4.87]. There was no statistically significant change from baseline to 24-week post-surgical measurement ($M = 57.44, SD = 23.06$), $t(8) = 1.84, p = .10$, or from 8-week pre-surgical measurement to 24-week post-surgical measurement, $t(8) = 2.1, p = .07$.

A 2x2 mixed model ANOVA analyzing baseline measurements and 8-week pre-surgical measurement of hamstrings at $180^\circ$/sec served as an interaction contrast of the exercise intervention at these two time periods. The interaction contrast was statistically significant for time x group, $F(1,16) = 9.23, p = .008, \eta^2_p = .37$.

Similarly, a 2x2 mixed model ANOVA was used to examine the interaction contrast between groups from baseline to 24-weeks post-surgical measurement. This interaction contrast was not statistically significance, $F(1,16) = 1.36, p = .26, \eta^2_p = .08$.  

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There was no statistically significant difference in peak torque between the groups from baseline to 24-weeks post-surgery.

An independent t-test compared differences in hamstrings peak torque at 180°/sec between the two groups at 24-weeks post-surgery. There was not a statistically significant difference in peak torque between the control ($M = 47.22, SD = 8.33$) and exercise group ($M = 57.44, SD = 23.06$), $t(16) = 1.25, p = .23$.

**Analysis of functional measure at 24-weeks post-surgical.** An independent t-test compared the differences in single leg hop tests scores between the groups at 24-weeks post-surgery. For this analysis, two participants in the control group were removed due to a score of zero. These two participants attempted the hop test, but were unable to complete the hop test because they could not land on the surgical leg. There is a statistically significant difference between the control ($n = 7, M = 69.66, SD = 14.25$) and the exercise group ($n = 9, M = 87.0, SD = 9.58$), $t(14) = 2.91, p = .011$. The mean difference was 17.34%, 95% CI [-30.11, – 4.58].

7.0 **Discussion**

The purpose of this study was to investigate the effectiveness of an eight week isokinetic exercise program for prehabilitation prior to ACLR and evaluate the effect on quadriceps strength and functional measures at 24-weeks postoperative. It was hypothesized that the prehabilitation program would be beneficial for strength gains and functional improvements. The outcome of this study confirmed that the implementation a prehabilitative exercise program had significant and positive effect on muscle strength and function. By increasing quadriceps peak torque before surgery, the exercise group
had greater quadriceps peak torque and single leg hop test distance when compared to the control group who did not participate in the exercise intervention.

Reduced quadriceps strength after ACLR is a common problem reported in numerous studies (de Jong et al., 2007; Kobayashi et al., 2004; Natri et al., 1996). However, more recently studies have shown that preoperative strength deficits contribute to even greater postoperative strength deficits (Shelbourne and Johnson, 2004; Keays et al., 2000; Eitzen et al., 2009). Eitzen et al. (2009) reported that patients with 20% deficit in quadriceps strength had greater impairment on functional knee scores and quadriceps strength testing. Keays et al. (2000) found patients with lower preoperative quadriceps deficits performed better (limb symmetry index score) at six to nine months postoperative. Shelbourne and Johnson (2004) reported that postoperative quadriceps strength was higher in patients with greater preoperative strength. Collectively, this research suggests that implementing a prehabilitation program to increase quadriceps strength before surgery would result in increased quadriceps peak torque and decreased deficit post-surgery. In my study, there was a statistically significant difference in 24-week postoperative quadriceps peak torque between the exercise and control groups. Although a statistical analysis was not conducted on the deficit values, the difference in strength deficits at 24-weeks postoperative at 60°/sec was 15.4% in the exercise group, and 35.9% in the control group. A similar study by Kim et al (2015) found differences in strength deficits at 12-weeks postoperative between preoperative exercise group (28.5%) and control (36.5%) group at 60°/sec.

This study demonstrated how increasing peak torque before surgery led to resulting greater peak torque in the exercise group at 24-weeks postoperative compared
to control group. After surgery, both groups lost similar mean foot pounds of torque at 60°/sec in the quadriceps. The control group lost 28 ft-lbs while the exercise group lost 24 ft-lbs. However, before surgery, the control group only improved by a mean 2.7 ft-lbs and the exercise group improved approximately 14-fold by 37 ft-lbs from baseline. Therefore, because the exercise group went into the surgery with stronger quadriceps, this strength gain was still reflected at 24-weeks postoperative with a difference of 43.2 ft-lbs between groups. At two velocities (60° and 120°/sec), the exercise group was stronger at 24-weeks postoperative than they were at baseline. At 60°/sec this interaction was significant when compared to the control group and at 120°/sec this approached statistical significance (p=.053). However, the control group was weaker at 24-weeks postoperative than they were at baseline at these same velocities.

Functional improvements in strength and power were measured in this study with the Single Leg Hop Test for distance. This test has long been considered important to determine successful return to sports after ACLR (Reid et al. 2007), and it has also been used for non-operative management with success (Fitzgerald, Axe, and Snyder-Mackler, 2000). The results of my study found statistically significant differences in single leg hop test scores between the exercise and control groups at 24-weeks postoperative, and supports previous research. Studies by both Kim et al. (2015) and Shaarani et al. (2013), found changes in single leg hop test scores following exercise rehabilitative training. Kim et al. (2015) reported statistically significant improvements in the exercise group’s score from preoperative to 12-weeks postoperative. Shaarani et al. (2013) found statistically significant differences between the exercise and control groups at both preoperative (after the exercise intervention) and 12-weeks postoperative time points.
Adding isokinetic exercise to prehabilitation protocols may help contribute to achieving increased quadriceps strengthening both before and after ACLR. No studies have investigated using isokinetic exercise to prehabilitate or rehabilitate ACL deficient knees. However, Tagesson et al. (2008) used open kinetic chain (OKC) rehabilitation protocol for ACL-deficient patients. At the four-month follow-up, the OKC group had improved isokinetic quadriceps strength over the closed kinetic chain (CKC) group at 60°/sec. A limited number of studies have also examined the use of isokinetics for rehabilitation post-ACLR (Fabiś, 2007; Mikkelsen et al., 2000). Mikkelsen et al. (2000) reported that patients in the group that trained with both OKC (isokinetic) + CKC exercises had better quadriceps torque at all speeds of contraction than the group that performed only CKC exercises at six-months postoperative. Fabiś (2007) found that following isokinetic training (20 minutes, five days per week at high velocities), the quadriceps peak torque deficit was reduced by 23.8% for quadriceps and 20.7% for hamstrings at six months postoperative. One study even found that a six-week isokinetic exercise program was successful in preventing extensor muscle power loss due to patellofemoral pain syndrome (Alaca et al., 2002). In my study, the eight-week isokinetic exercise intervention improved peak torque in quadriceps at all three speeds (60, 120 and 180°/sec) and improved hamstring peak torque at 120 and 180°/sec to a level of statistical significance (p<0.05). Thus, the literature supports the findings of the current structured exercise prehabilitation study, and furthermore advocates its use as a prophylactic measure to minimize the functional deficits that will occur if quadriceps insufficiencies persist.
Grindem et al. (2014) reported the success of the Norwegian Research Centre for Active Rehabilitation (NAR) cohort who undertook the progressive preoperative and postoperative program. They showed superior results on the Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire at two years postoperative compared to the patients who received “usual care.” The patients in the pre- and postoperative program were part of the NAR program, and were also reported in an earlier study by Eitzen et al. (2010). The patients in the NAR cohort received this treatment two times per week at a sports medicine clinic. The aim of the programming was for the patients to achieve 90% hamstring and quadriceps strength as well as 90% hop performance prior to surgery, when compared to the non-surgical leg. These outstanding results have led to some speculation that receiving treatment in specialized sports medical clinics provides additional advantages beyond the rehabilitation program alone (Hägglund, Walden and Thomeé, 2015). The response has been that the intensity of the NAR program as well as the contact with clinicians and their ability to contribute to patient education, goal-setting and repeated functional testing contributed to the success of the study (Grindem, Risberg and Eitzen, 2015). The goal to achieve 90% quadriceps and hamstrings strength as well as 90% hop test symmetry should be further examined for future prehabilitation programs. In the current study, the exercise group fully recovered their baseline deficit after four weeks of isokinetic training was added to their regular exercise program. This supports using isokinetic training as part of an intense prehabilitation regime.

In the literature, hamstring deficits aren’t noted as much of a concern either before or after ACLR. Shaarani et al. (2013) reported a significant increase in hamstring
peak torque (90°/sec) preoperatively from baseline in both the exercise and control groups. Shaarani et al. also noted no significant differences in hamstring peak torque between groups at pre- and postoperative time points. The results presented here showed increases in peak torque from the exercise intervention were statistically significant between groups at faster velocities (120°/sec and 180°/sec), and approached statistical significance (p=.055) at the slower velocities (60°/sec). Kobayashi et al. (2004) noted that flexors recovered to 90% of the strength of the non-surgical leg by 24-weeks postoperative. Natri et al. (1996) also concluded that significant hamstring deficits were present four years postoperative. My study found changes over time, between groups were statistically significant at 180°/sec, but comparisons at 24-weeks postoperative were not significant.

7.1 Limitations

Limitations of this study include the small sample size of 18 participants for outcome measures. The length of follow-up for physical outcomes was also limited to 24-weeks postoperative. Long-term follow-up is needed to determine if these positive results continue in the months and years to come. Long-term follow-up could also include return to sport/activity timelines and re-injury reports.

Circadian rhythm was not accounted for on testing dates. Nine of the participants were tested at roughly the same time of day (within three hours), however, the other nine had appointments that varied in times (exceeding three hours). The distribution was even between groups, five from one group and four from the other had either similar or differing test times. As an example, one participant had two testing appointments at 4:00 p.m., and one appointment at 7:00 a.m. One study has found that time of day can impact
strength measures with quadriceps dynamometry (Coldwells, Atkinson & Reilly, 1994). However, a more recent study indicated that the research is inconclusive on circadian rhythms and the effect on sport performance (Drust, Waterhouse & Atkinson, 2005). More work still needs to be done in this area, however, this was not controlled for in this study and could have potentially impacted the results.

Although this study used isokinetic training and testing methods to show beneficial functional and strength changes, future studies using traditional free weights is a viable option for patients. Recent studies have demonstrated success with more traditional strengthening programs (Kim et al., 2015; Shaarani et al., 2013).

7.2 Conclusion

This study revealed that participants in the isokinetic exercise group had higher quadriceps peak torque both pre- and postoperatively compared to the control group. This increased peak torque lead to improved function as reflected in the single leg hop tests scores. These results indicate that improving quadriceps strength preoperatively contributes to stronger quadriceps strength postoperatively. This study supports prehabilitation for patients awaiting ACLR. However, further studies need to focus on developing guidelines and protocols for prehabilitation programs. Longitudinal research could investigate if these early results continue into the following years post-ACLR. Future research could include details on return to sport outcomes.
References


10.1177/0363546513493594

10.1177/0363546503262171


doi:10.1177/0363546504271211

Tagesson, S., Öberg, B., Good, L., & Kvist, J. (2008). A comprehensive rehabilitation program with quadriceps strengthening in closed versus open kinetic chain


Appendices

Appendix A: Informed Consent Documentation

Appendix B: Research Ethics Board Letter of Approval

- Please see attached pages to follow:
RESEARCH PROJECT TITLE:
The Effect of Isokinetic Exercise for Pre-habilitation: ACL Reconstruction

PRINCIPAL RESEARCHERS:
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PURPOSE:
The purpose of this study is to investigate the effectiveness of a prehabilitation isokinetic exercise program before anterior cruciate ligament reconstruction (ACL) surgery.

METHODS:
Experimental Design of the project
Individuals that are cleared to enter this study will complete necessary medical forms and informed consent. Female and male participants will be randomized into the experimental and control group. Physical characteristics (height, weight), medical history (duration of knee injury, current exercise and physical activity, previous injuries to the uninvolved leg, other medical history and medications), as well as resting heart rate and blood pressure will be recorded. Trained researchers (Canadian Society for Exercise Physiology certifications) will be conducting all physiological testing.

Cybex 6000 Isokinetic Dynamometer
The Cybex 6000 Isokinetic Dynamometer will be used to measure peak torque of knee extensor and flexor muscles. Isokinetic devices work by controlling the speed of muscle contraction when a maximal force is applying throughout the full range of motion. The speed of joint motion is constant and the force is dependent on how hard the individual exerts force. All participants will be tested at three different velocities (60, 90, 120 degrees/sec), 4 times over the 8 weeks before surgery (baseline, 4 wks, 8 wks) and at 3 and 6 months post-operative. Isokinetic testing is a maximal effort. This device will also be used for the pre-habilitation exercise program that the exercise group will perform. Participants in the exercise group will exercise on this machine 3x/wk for 8 weeks prior to ACLR. Cybex is non-invasive, has been used in hundreds of research studies, and we are not aware of any complications because of its use. Previous research supports the safety and efficacy of isokinetic testing (Maitland et al., 1993). Other research studies within the Faculty of Kinesiology & Health Studies at the University of Regina have also received ethical approval using Cybex (#70R-0910).
Muscle Ultrasound/ DXA imaging and Oxygenation
An ultrasound of the quadriceps muscle will be performed to determine changes in muscle tissue size during this study. Also a DXA scan (Dual-energy X-ray absorptiometry) of the lower body will be done as well which records the changes in muscle, bone, and fat tissue. Both of these techniques are non-invasive and have been performed on hundreds of participants with ethical approval from the University of Regina (REB#16R0910; #62R0890). Muscle oxygenation will be monitored non-invasively and poses no risks, and has received ethical clearance in our previous research (REB#70R0910).

Knee Injury and Osteoarthritis Outcome Score (KOOS)
The Knee injury and Osteoarthritis Outcome Score (KOOS), was developed in 1998. The KOOS is a 42-item self-administered, self-explanatory questionnaire that covers five relevant pain dimensions: Pain, Other Disease Specific Symptoms, ADL Function, Sport and Recreation Function, and knee-related Quality of Life. A Likert scale is used and all items have five possible answer options from 0 (no problems) to 4 (Extreme Problems). The KOOS takes approximately ten minutes to complete. The KOOS will be completed by all participants at the 3 testing intervals prior to ACLR and at 3 and 6 months post-operative.

POTENTIAL RISKS: The Cybex isokinetic testing and exercise involves maximal effort, and the participant may feel fatigued during the exercise. If the participant feels they need to stop, at any time or for any reason, they may do so without penalty. Due to the intensity of the exercise, participants may also feel delayed onset muscle soreness (DOMS) after exercise but this is a normal physiological response to high intensity exercise. DOMS is temporary, and symptoms will decrease as strength improves. With the DXA scans, there is a small amount of radiation exposure. The amount of radiation from these scans is about 1/20th of the amount of radiation you would receive from taking a trans-Atlantic flight from North American to Europe.

POTENTIAL BENEFITS: This research study may provide the participant with an opportunity to improve leg strength prior to ACLR surgery. Improving strength before surgery through a pre-habilitation exercise program could potentially result in improved post-surgical strength, a more effective rehabilitation, and improved recovery. Improved rehabilitation would result in decreased quadriceps muscle deficit of the surgical leg, which may decrease the risk of developing osteoarthritis later in life. Participation in this study will also provide us, the researchers, with valuable information on the effectiveness of isokinetic exercise as a pre-habilitation protocol prior to ACLR.

EXPLANATION OF RESULTS: You will be given a thorough explanation of your own test results for each test, and you may request a copy of your own personal results when this study is completed.

If you wish to contact the Surgeon, Dr. Jeremy Reed, regarding your participation in this study you can do so at Jeremy.reed@uregina.ca, or 306-337-2130. If you would like to contact an independent person regarding any aspect of participation in this study, please contact: Research Ethics Board, Office of Research Services, University of Regina, Phone: (306) 585-4775; E-mail: research.ethics@uregina.ca.

Participation is voluntary and you may withdraw at any time without penalty. Please complete the section on the following page. Thank you for your participation!
Consent for Participants to Participate in this Research Project

Title of Project: The Effect of Isokinetic Exercise for Pre-habilitation: ACL Reconstruction REB #110R11213

- I understand that my participation in this study is voluntary and that I may withdraw my participation in this experiment at any time, without any consequences. I understand that my withdrawal will not affect any future medical treatment that I may receive as a client in the Dr. Paul Schwann Centre.

- I have been informed that the researchers will protect my privacy, and safeguard the confidentiality of information collected about me during the course of this study. I understand that my information will be stored in a secured area, and on a password protected computer in the Dr. Paul Schwann Centre, with access available to graduate student Erin Tyson and Dr. Patrick Neary.

- I have been assured that I may contact Erin Tyson (erin.tyson@uregina.ca; 306-585-5293), Dr. J. Patrick Neary (patrick.neary@uregina.ca; 306-585-4844), Dr. Darren Cadow (Darren.cadow@uregina.ca), Dr Jeremy Reed (jgreed@ucalgary.ca), Dr Megan Dash (megan.dash@usask.ca) or Dr. June Zimmer (jnec.zimmer@usask.ca) if I have questions or would like more information about this study. I understand that I can obtain a copy of my results, upon completion of the study, by contacting any of the above researchers.

- I understand that I can register any concerns I have about this experiment with the Research Ethics Committee, University of Regina. Phone: 306-585-4775; Email: research.ethics@uregina.ca.

- I understand the contents of this form, and I agree to voluntarily participate in this research study.

- I have received a copy of the information sheet and this informed consent form for my records.

NAME (Please print legibly): ____________________________________________

ADDRESS: __________________________________________________________________

SIGNATURE: __________________________________________________________________

PARENT/GUARDIAN (if under 18yrs): __________________________

DATE: __________________________

June 10, 2013
DATE: July 9, 2013

TO: Dr. J. Patrick Neary
Kinesiology and Health Studies

FROM: Dr. Larena Hoeber,
Chair, Research Ethics Board

Re: The Effect of Isokinetic Exercise for Pre-habilitation: ACL Reconstruction File # 110R1213

This memo confirms approval of the changes outlined in your e-mail memo dated July 5, 2013.

Please contact us if you have any further questions.

Sincerely,

Dr. Larena Hoeber,
Chair, Research Ethics Board